Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Lake Worth

Tarrant County, Texas

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INTRODUCTION

In August 1990, the United States Environmental Protection Agency (USEPA) placed Air Force Plant No. 4 (AFP4) on the USEPA National Priorities List (NPL) as a Superfund site. The site was listed primarily because past activities had resulted in the contamination of groundwater in the superficial and deeper aquifers.[1] In 1998, the Texas Department of Health (TDH)[a] and the Agency for Toxic Substances and Disease Registry (ATSDR) released a public health assessment (PHA) for the AFP4 site. During the preparation of the PHA, TDH reviewed sampling data from small nonedible fish, known as mosquito fish, collected from five locations along Lake Worth and Meandering Road Creek. TDH noted that the mosquito fish collected adjacent to AFP4 had higher concentrations of polychlorinated biphenyls (PCBs), dieldrin, naphthalene, and poly-aromatic hydrocarbons (PAHs; phenanthrene and benzo(b)fluoranthene) than those collected from the background locations. Although edible species of fish routinely consumed from Lake Worth were not available for the PHA, based on the mosquito fish findings, TDH and ATSDR recommended that the United States Air Force (USAF) collect edible fish from Lake Worth to determine whether eating fish from the reservoir poses a threat to public health.

In response to this recommendation, the United States Geological Survey (USGS) in cooperation with the USAF collected and analyzed edible fish from Lake Worth and provided the data to the TDH Seafood Safety Division[b] for evaluation. In March and April 1999, the USGS collected 55 fish samples from several sites in Lake Worth.[2] Left side, skin-off fillet samples were collected from 10 individuals each of channel catfish, common carp, freshwater drum, largemouth bass, and white crappie and five smallmouth buffalo. The USGS National Water Quality Laboratory analyzed the samples for selected trace metals, organochlorine pesticides, polychlorinated biphenyls (PCBs), and semivolatile organic compounds (SVOCs). The results of this investigation showed widespread contamination of fish from Lake Worth due to PCBs at concentrations exceeding TDH guidelines for protection of human health.[3] On April 19, 2000, TDH issued Fish and Shellfish Consumption Advisory 18 (ADV-18) recommending that people should not consume fish from Lake Worth.[4] The Texas Commission on Environmental Quality (TCEQ) requested the present survey of Lake Worth as a follow-up study under the Total Maximum Daily Load (TMDL) program.

Description of Lake Worth

Lake Worth is a 3,489-acre impoundment of the West Fork Trinity River located within the city limits of Fort Worth, Texas in northwest Tarrant County.[5] The reservoir was constructed in 1914 by the City of Fort Worth to provide a municipal water supply. The reservoir extends approximately 6 miles upstream from the dam and drains a 2,064-square mile watershed. Three tributary creeks (Silver Creek, Live Oak Creek, and Meandering Road Creek) representing approximately 94 square miles of the Lake Worth watershed have contributed most of the flow to the reservoir due to the construction of Eagle Mountain Lake, an upstream reservoir, in 1932.[6] The reservoir is bordered by the Fort Worth Nature Center and Refuge at the upstream end of the

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[a] Now the Department of State Health Services (DSHS)
[b] Now the Seafood and Aquatic Life Group (SALG)

lake and residential and commercial properties surround most of the lake. Two large industrial facilities are located adjacent to the south side of the reservoir: United States Air Station Joint Reserve Base–Fort Worth (NASFW) and AFP4. Lake Worth is a shallow, eutrophic reservoir. Fishery habitat is primarily composed of rocky and gravel shorelines, shallow flats with emergent aquatic vegetation, and standing timber. The reservoir's numerous boat docks also provide valuable structure and cover for fish. There are three parks and one marina that provide public access to the lake.[7] The lake is also known by recreational fishers for its abundance of crappie and catfish.

Demographics of Tarrant County Surrounding the Area of the Lake Worth

Tarrant County is part of the Dallas-Fort Worth-Arlington metropolitan area, locally referred to as the "The Metroplex". The Metroplex is the largest metropolitan area in the state of Texas and the fourth largest in the United States.[8] In 2008, according to the United States Census Bureau's (USCB) estimate, the 12 county Dallas-Fort Worth-Arlington metropolitan area has a population near 6,300,006.[8] The USCB also reported that the Dallas-Fort Worth-Arlington metropolitan area is the fastest growing metropolitan area in the United States, which gained 1,138,476 residents from April 1, 2000 to July 1, 2008.[8] The Metroplex covers approximately 9,286 square miles; an area larger than the combined U.S. states of Connecticut and Rhode Island.

Subsistence Fishing in Lake Worth

The USEPA suggests that, along with ethnic characteristics and cultural practices of an area's population, the poverty rate could contribute to the rate of subsistence fishing in an area.[9] The DSHS finds, in concert with the USEPA, that it is important to consider subsistence fishing to occur at any water body because subsistence fishers (as well as recreational anglers and certain tribal and ethnic groups) usually consume more locally caught fish than the general population. These groups sometimes harvest fish or shellfish from the same water body over many years to supplement caloric and protein intake. People who routinely eat chemically contaminated fish or shellfish from a water body – or those who eat large quantities of fish from the same waters – could unknowingly increase their risk of adverse health effects from that consumption. The USEPA suggests that states assume that at least 10% of licensed fishers in any area are subsistence fishers. Subsistence fishing, while not explicitly documented by the DSHS, likely does occur. The DSHS assumes the rate of subsistence fishing to be similar to that estimated by the USEPA.[9]

The TMDL Program at the TCEQ and the Relationship between the TMDL Program and Consumption Advisories or Possession Bans Issued by the DSHS

The TCEQ enforces federal and state laws that promote judicious use of water bodies under state jurisdiction and protects state-controlled water bodies from pollution. Pursuant to the federal Clean Water Act, Section 303(d),[10] all states must establish a TMDL for each pollutant contributing to the impairment of a water body for one or more designated uses. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and non-point sources. TMDLs incorporate margins of safety to ensure the usability of the water body for all designated purposes and to account for seasonal variations in water quality. States, territories, and tribes define the uses for a specific water body (e.g., drinking water, contact recreation, aquatic life support) along with the scientific criteria designated to support each specified use.[7]

Fish consumption is a recognized use for many waters. A water body is impaired if fish from that water body contain contaminants that make those fish unfit for human consumption or if consumption of those contaminants potentially could harm human health. Although a water body and its aquatic life may clear toxicants over time with removal of the source(s), it is often necessary to institute some type of remediation such as those devised by the TCEQ. Thus, whenever the DSHS issues a fish consumption advisory or prohibits possession of environmentally contaminated fish, the TCEQ automatically places the water body on its current draft 303(d) List.[7] TMDL staff members then prepare a TMDL for each contaminant present at concentrations that, if consumed, would be capable of negatively affecting human health. After approval of the TMDL, the group prepares an Implementation Plan for each contaminant. Upon "implementation," these plans facilitate rehabilitation of the water body. Successful remediation should result in return of the water body to conditions compatible with all stated uses, including consumption of fish from the water body. When the DSHS lifts a consumption advisory or possession ban, people may once again keep and consume fish from the water body. If fish in a water body are contaminated, one of the several items on an Implementation Plan for a water body on a state's 303(d) list consists of the periodic reassessment of contaminant levels in resident fish.

METHODS

Fish Sampling, Preparation, and Analysis

The DSHS Seafood and Aquatic Life Group (SALG) collects and analyzes edible fish from the state's public waters to evaluate potential risks to the health of people consuming contaminated fish or shellfish. Fish tissue sampling follows standard operating procedures from the DSHS *Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual.*[11] The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the USEPA in that agency's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1*.[12] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS).*[13] Samples usually represent species, trophic levels, and legal-sized specimens available for consumption from a water body. When practical, the DSHS collects samples from two or more sites within a water body to better characterize geographical distributions of contaminants.

Fish Sampling Methods and Description of the Lake Worth 2008 Sample Set

In October 2008, SALG staff collected 80 fish samples from Lake Worth. Risk assessors used data from these fish to assess the potential for adverse human health outcomes from consuming fish from this reservoir.

Ten sites were assigned to provide spatial coverage of the study area (see Figure 1 for approximate locations). Site 1 was located at the Dam, Site 2 near the Naval Air Station, Site 3 near Carswell Field Runway, Site 4 at the Meandering Road Creek Mouth, Site 5 at Woods Inlet, Site 6 at the Live Oak Creek Mouth, Site 7 near Woods Island, Site 8 near Mosque Point, Site 9 at SH 199 Bridge, and Site 10 at West Fork Trinity River. Species collected represent distinct ecological groups (i.e. predators and bottom feeders) that have some potential to bioaccumulate chemical contaminants, have a wide geographic distribution, are of local recreational fishing value, and/or that anglers and their families commonly consume. The 80 fish collected from Lake Worth represented all species targeted for collection from this water body. Table 1 lists species sampled, the number of each species collected, and the length and weight (in metric units) of each sample from each collection site. Fish species for the 2008 Lake Worth project are listed in descending order by number of each species collected: largemouth bass (19), channel catfish (18), freshwater drum (10), smallmouth buffalo (10), white crappie (10), common carp (9), and blue catfish (4).

The SALG set gill nets in the late afternoon at each of the sample sites and fished those sites overnight. The gill nets were set in locations to maximize available cover and habitat. Staff retrieved captured fishes from the gill nets in the early morning hours, retaining only fish pre-selected as target samples. Staff immediately stored retrieved samples on wet ice in large coolers to ensure interim preservation, returning live fish culled from the catch to the water body.

The SALG utilized a boat-mounted electrofisher to collect fish. The SALG staff conducted electrofishing activities during daylight hours using pulsed direct current (Smith Root 7.5 GPP electrofishing system settings: 6.0-8.0 amps, 60 pulses per second [pps], low range, 500 volts, 40-50% duty cycle) to stun fish that crossed the electric field in the water in front of the boat. Staff used dip nets over the bow of the boat to retrieve stunned fish, netting only fish pre-selected as target samples. Staff immediately stored retrieved samples on wet ice in large coolers to enhance tissue preservation.

SALG staff processed fish onsite at Lake Worth**.** Staff weighed each sample to the nearest gram (g) on an electronic scale and measured total length (tip of nose to tip of tail fin) to the nearest millimeter (mm). After weighing and measuring a fish, staff used a cutting board covered with aluminum foil and a fillet knife to prepare two skin-off fillets from each fish. The foil was changed and the knife cleaned with distilled water after each sample was processed. The team wrapped fillet(s) in two layers of fresh aluminum foil, placed in an unused, clean, pre-labeled plastic freezer bag, and stored on wet ice in an insulated chest until further processing. The SALG staff transported tissue samples on wet ice to their Austin, Texas, headquarters, where the samples were stored temporarily at -5° Fahrenheit (-20° Celsius) in a locked freezer. The freezer key is accessible only to authorized SALG staff members to ensure the chain of custody remains intact while samples are in the possession of agency staff. The week following the collection trip, the SALG delivered frozen fish tissue samples to the Geochemical and Environmental Research Group (GERG) Laboratory, Texas A&M University, College Station, Texas, for contaminant analysis.

Analytical Laboratory Information

Upon arrival of the samples at the laboratory, GERG personnel notified the SALG of receipt of the 80 Lake Worth samples and recorded the condition of each sample along with its DSHS identification number.

Using established USEPA methods, the GERG laboratory analyzed fish fillets from Lake Worth for inorganic and organic contaminants commonly identified in polluted environmental media. Analyses included seven metals (arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 SVOCs, 70 volatile organic contaminants (VOCs), 34 pesticides, 209 PCB congeners, and 17 polychlorinated dibenzofurans and/or dibenzo-*p*-dioxins (PCDFs/PCDDs) congeners. The laboratory analyzed all 80 samples for PCBs. A subset of 16 samples was selected for metals, pesticides, SVOCs, VOCs, and PCDFs/PCDDs analyses.[14]

Explanatory Details of Specific Analyses

Arsenic

The GERG laboratory analyzed each of four fish for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[15] DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentration in each fish by multiplying reported total arsenic concentration in the sample by a factor of 0.1.[15]

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[16] Thus, the total mercury concentration in a fish of legal size for possession in Texas serves well as a surrogate for methylmercury concentration. Because methylmercury analyses are difficult to perform accurately and are more expensive than total mercury analyses, the USEPA recommends that states determine total mercury concentration in a fish and that – to protect human health – states conservatively assume that all reported mercury in fish or shellfish is methylmercury. The GERG laboratory thus analyzed fish tissues for total mercury. In its risk characterizations, DSHS compares mercury concentrations in tissues to a comparison value derived from the Agency for Toxic Substances and Disease Registry's (ATSDR) minimal risk level (MRL) for methylmercury (in these risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish).[17]

Polychlorinated Biphenyls (PCBs)

For PCBs, the USEPA suggests that each state measures congeners of PCBs in fish and shellfish rather than homologs or Aroclors® because the USEPA considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[14] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the U.S., the GERG laboratory analyzes and reports the presence and concentrations of all 209 possible PCB congeners. From the congener analyses, the laboratory also computes and reports concentrations of PCB homologs and of Aroclor® mixtures. Despite the USEPA's suggestion that the states utilize PCB congeners rather than Aroclors® or homologs for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[18] from McFarland and Clarke,[19] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish[12,14] to address PCB congeners in fish and shellfish samples, selecting the 43 congeners encompassed by the McFarland and Clark and the NOAA articles. The referenced authors chose to use congeners that were relatively abundant in the environment, were likely to occur in aquatic life, and were most likely – as projected from structure –activity relationships – to show assessable toxicity.[18,19] SALG risk assessors summed the 43 congeners to derive "total" PCB concentration in each sample.[18,19] SALG risk assessors then averaged the summed congeners within each group (e.g., fish species, sample site, or combination of species and site) to derive a mean PCB concentration for each group.

Using only a few PCB congeners to determine total PCB concentrations could underestimate PCB levels in fish tissue. Nonetheless, the method complies with expert recommendations on evaluation of PCBs in fish or shellfish. Therefore, SALG risk assessors compare average PCB concentrations of the 43 congeners with health assessment comparison (HAC) values derived from information on PCB mixtures held in the USEPA's Integrated Risk Information System (IRIS) database.[20] IRIS currently contains systemic toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. IRIS does not contain all information for all mixtures. For instance, only one other reference dose (RfD) occurs in IRIS – the one derived for Aroclor 1016, a commercial mixture produced in the latter years of commercial production of PCBs in the US. Aroclor 1016 was a fraction of Aroclor 1254 that was supposedly devoid of dibenzofurans, in contrast to Aroclor 1254.[21] Systemic toxicity estimates in the present document reflect comparisons derived from the USEPA's RfD for Aroclor 1254 because Aroclor 1254 contains many of the 43 congeners selected by McFarland and Clark and NOAA, and because, as of yet, IRIS does not contain information on the systemic toxicity of individual PCB congeners.

For assessment of cancer risk from exposure to PCBs, the SALG uses the USEPA's highest slope factor of 2.0 per (mg/kg/day) to calculate the probability of lifetime excess cancer risk from PCB ingestion. The SALG based its decision to use the most restrictive slope factor available for PCBs on factors such as food chain exposure; the presence of dioxin-like, tumor-promoting, or persistent congeners; and the likelihood of early-life exposure.[22]

Calculation of Toxicity Equivalent Quotients (TEQs) for Dioxins

PCDDs/PCDFs are families of aromatic chemicals containing one to eight chlorine atoms. The molecular structures differ not only with respect to the number of chlorines on the molecule, but also with the positions of those chlorines on the carbons atoms of the molecule. The number and positions of the chlorines on the dibenzofuran or dibenzo-*p*-dioxin nucleus directly affects the toxicity of the various congeners. Toxicity increases as the number of chlorines increases to four chlorines, then decreases with increasing numbers of chlorine atoms - up to a maximum of eight. With respect to the position of chlorines on the dibenzo-*p*-dioxin/dibenzofuran nucleus, it appears that those congeners with chlorine substitutions in the 2, 3, 7, and 8 positions are more toxic than congeners with chlorine substitutions in other positions. To illustrate, the most toxic of PCDDs is 2,3,7,8–tetrachlorodibenzo-*p*-dioxin (2,3,7,8–TCDD), a 4-chlorine molecule having one chlorine substituted for hydrogen at each of the 2, 3, 7, and 8 carbon positions on the dibenzo-*p*-dioxin. To gain some measure of toxic equivalence, 2,3,7,8–TCDD – assigned a toxicity equivalency factor (TEF) of 1.0 – is the standard against which other congeners are measured. Other congeners are given weighting factors or TEFs of 1.0 or less based on experiments comparing the toxicity of the congener relative to that of 2,3,7,8-TCDD.[23, 24] Using this technique, risk assessors from the DSHS converted PCDF or PCDD congeners in each tissue sample from the present survey to TEQs by multiplying each congener's concentration by its TEF, producing a dose roughly equivalent in toxicity to that of the same dose of 2,3,7,8-TCDD. The total TEQ for any sample is the sum of the TEQs for each of the congeners in the sample, calculated according to the following formula.[25]

$$\text{Total TEQs} = \sum_{i=1}^{n}(\text{CI} \times \text{TEF})$$

CI = concentration of a given congener
TEF = toxicity equivalence factor for the given congener
n = # of congeners
i = initial congener
∑ = sum

Derivation and Application of Health-Based Assessment Comparison Values for Systemic Effects (HAC_{nonca}) of Consumed Chemical Contaminants

The effects of exposure to any hazardous substance depend, among other factors, on the dose, the route of exposure, the duration of exposure, the manner in which the exposure occurs, the genetic makeup, personal traits, habits of the exposed, or the presence of other chemicals.[26] People who regularly consume contaminated fish or shellfish conceivably suffer repeated low-dose exposures to contaminants in fish or shellfish over extended periods (episodic exposures to low doses). Such exposures are unlikely to result in acute toxicity but may increase risk of subtle, chronic, and/or delayed adverse health effects that may include cancer, benign tumors, birth defects, infertility, blood disorders, brain damage, peripheral nerve damage, lung disease, and kidney disease.[26]

If diverse species of fish or shellfish are available, the SALG presumes that people eat a variety of species from a water body. Further, SALG risk assessors assume that most fish species are mobile. SALG risk assessors may combine data from different fish species, blue crab, and/or sampling sites within a water body to evaluate mean contaminant concentrations of toxicants in all samples as a whole. This approach intuitively reflects consumers' likely exposure over time to contaminants in fish or shellfish from any water body but may not reflect the reality of exposure at a specific water body or a single point in time. The DSHS may project risks associated with ingestion of individual species of fish or shellfish from separate collection sites within a water body or at higher than average concentrations (e.g. the upper 95 percent confidence limit on the mean). The SALG derives confidence intervals from Monte Carlo simulations using software developed by a DSHS medical epidemiologist.[27] The SALG evaluates contaminants in fish or shellfish by comparing the mean or the 95% upper confidence limit on the mean concentration of a contaminant to its HAC value (in mg/kg) for non-cancer or cancer endpoints.

In deriving HAC values for systemic (HAC_{nonca}) effects, the SALG assumes a standard adult weighs 70 kilograms and consumes 30 grams of fish or shellfish per day (about one 8-ounce meal per week) and uses the USEPA's RfD[28] or the ATSDR's chronic oral MRLs.[29] The USEPA defines an RfD as

> *An estimate of a daily oral exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime.*[30]

The USEPA also states that the RfD

> … *is derived from a BMDL* (benchmark dose lower confidence limit)*, a NOAEL* (no observed adverse effect level)*, a LOAEL* (lowest observed adverse effect level)*, or another suitable point of departure, with uncertainty/variability factors applied to reflect limitations of the data used. [Durations include acute, short-term, subchronic, and chronic and are defined individually in this glossary]* and *RfDs are generally reserved for health effects thought to have a threshold or a low dose limit for producing effects.*[30]

The ATSDR uses a similar technique to derive its MRLs.[29] The DSHS divides the estimated daily dose derived from the measured concentration in fish tissue by the contaminant's RfD or MRL to derive a hazard quotient (HQ). The USEPA defines an HQ as

> *…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).*[31]

Note that, according to the USEPA, a linear increase in the HQ for a toxicant does not imply a linear increase in the likelihood or severity of systemic adverse effects. Thus, an HQ of 4.0 does not mean the concentration in the dose will be four times as toxic as that same substance would be if the HQ were equal to 1.0. An HQ of 4.0 also does not imply that adverse events will occur four times as often as if the HQ for the substance in question were 1.0. Rather, the USEPA suggests that a HQ or a hazard index (HI) – defined as the sum of HQs for contaminants to which an individual is exposed simultaneously) – that computes to less than 1.0 should be interpreted as "no cause for concern" whereas a HQ or HI greater than 1.0 "should indicate some cause for concern."

The SALG does not utilize HQs to determine the likelihood of occurrence of adverse systemic health effects. Instead, in a manner similar to the USEPA's decision process, the SALG may utilize computed HQs as a qualitative measurement. Qualitatively, HQs less than 1.0 are unlikely to be an issue while HQs greater than 1.0 might suggest a regulatory action to ensure protection of public health. Similarly, risk assessors at the DSHS may utilize an HQ to determine the need for further study of a water body's fauna. Notwithstanding the above discussion, the oral RfD derived by the USEPA represents chronic consumption. Thus, regularly eating fish containing a toxic chemical, the HQ of which is less than 1.0 is unlikely to cause adverse systemic health effects, whereas routine consumption of fish or shellfish in which the HQ exceeds 1.0 represents a qualitatively unacceptable increase in the likelihood of systemic adverse health outcomes.

Although the DSHS utilizes chemical specific RfDs when possible, if an RfD is not available for a contaminant, the USEPA advises risk assessors to consider evaluating the contaminant by comparing it to the published RfD (or the MRL) of a contaminant of similar molecular structure or one with a similar mode or mechanism of action. For instance, Aroclor® 1260 has no RfD, so the DSHS uses the reference dose for Aroclor 1254 to assess the likelihood of systemic (noncarcinogenic) effects of Aroclor 1260.[28]

In developing oral RfDs and MRLs, federal scientists review the extant literature to devise NOAELs, LOAELs, or benchmark doses (BMDs) from experimental studies. Uncertainty factors are then utilized to minimize potential systemic adverse health effects in people who are exposed through consumption of contaminated materials by accounting for certain conditions that may be undetermined by the experimental data. These include extrapolation from animals to humans (interspecies variability), intra-human variability, use of a subchronic study rather than a chronic study to determine the NOAEL, LOAEL, or BMD, and database insufficiencies.[28,30] Vulnerable groups such as women who are pregnant or lactating, women who may become pregnant, infants, children, people with chronic illnesses, those with compromised immune systems, the elderly, or those who consume exceptionally large servings are considered sensitive populations by risk assessors and USEPA and also receive special consideration in calculation of a RfD.[30, 32]

The primary method for assessing the toxicity of component-based mixtures of chemicals in environmental media is the HI. The USEPA recommends HI methodology for groups of toxicologically similar chemicals or chemicals that affect the same target organ. The HI for the toxic effects of a chemical mixture on a single target organ is actually a simulated HQ calculated as if the mixture were a single chemical. The default procedure for calculating the HI for the exposure mixture is to add the hazard quotients (the ratio of the external exposure dose to the RfD) for all the mixture’s component chemicals that affect the same target organ, e.g., the liver. The toxicity of a particular mixture on the liver represented by the HI should approximate the toxicity that would have occurred were the observed effects caused by a higher dose of a single toxicant (additive effects). The components to be included in the HI calculation are any chemical components of the mixture that show the effect described by the HI, regardless of the critical effect from which the RfD came. Assessors should calculate a separate HI for each toxic effect.

Because the RfD is derived for the critical effect (the "toxic effect occurring at the lowest dose of a chemical"), an HI computed from HQs based on the RfDs for the separate chemicals may be overly conservative. That is, using RfDs to calculate HIs may exaggerate health risks from consumption of specific mixtures for which no experimentally derived information is available.

The USEPA states that

> *the HI is a quantitative decision aid that requires toxicity values as well as exposure estimates. When each organ-specific HI for a mixture is less than one and all relevant effects have been considered in the assessment, the exposure being assessed for potential systemic toxicity should be interpreted as unlikely to result in significant toxicity.*

And

> *When any effect-specific HI exceeds one, concern exists over potential toxicity. As more HIs for different effects exceed one, the potential for human toxicity also increases.*

Thus,

> *Concern should increase as the number of effect-specific HIs exceeding one increases. As a larger number of effect-specific HIs exceed one, concern over potential toxicity should also increase. As with HQs, this potential for risk is not the same as probabilistic risk; a doubling of the HI does not necessarily indicate a doubling of toxic risk.*

Derivation and Application of Health-Based Assessment Comparison Values for Application to the Carcinogenic Effects (HAC_{ca}) of Consumed Chemical Contaminants

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the USEPA's chemical-specific cancer potency factors (CPFs), also known as cancer slope factors (CSFs), derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for carcinogens, using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. The SALG risk assessors incorporate two additional factors into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL) [30] of one excess cancer case in 10,000 persons whose average daily exposure is equivalent and (2) daily exposure for 30 years, a modification of the 70-year lifetime exposure assumed by the USEPA. Comparison values used to assess the probability of cancer do not contain "uncertainty" factors. However, conclusions drawn from probability determinations infer substantial safety margins for all people by virtue of the models utilized to derive the slope factors (cancer potency factors) used in calculating the HAC_{ca}.

Because the calculated comparison values (HAC values) are conservative, exceeding a HAC value does not necessarily mean adverse health effects will occur. The perceived strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool used by risk managers along with other information to make decisions about the degree of risk incurred by those who consume contaminated fish or shellfish. Moreover, comparison values for adverse health effects do not represent sharp dividing lines (obvious demarcations) between safe and unsafe exposures. For example, the DSHS considers it unacceptable when consumption of four or fewer meals per month of contaminated fish or shellfish would result in exposure to contaminant(s) in excess of a HAC value or other measure of risk. The DSHS also advises people who wish to minimize exposure to contaminants in fish or shellfish to eat a variety of fish and/or shellfish and to limit consumption of those species most likely to contain toxic contaminants. The DSHS aims to protect vulnerable subpopulations with its consumption advice, assuming that advice protective of vulnerable subgroups will also protect the general population from potential adverse health effects associated with consumption of contaminated fish or shellfish.

Children's Health Considerations

The DSHS recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and suggests that exceptional susceptibilities demand special attention.[33, 34] Windows of special vulnerability (known as "critical developmental periods") exist during development. Critical periods occur particularly during early gestation (weeks 0 through 8) but can occur at any time during development (pregnancy, infancy, childhood, or adolescence) – times when toxicants can impair or alter the structure or function of susceptible systems.[35] Unique early sensitivities may exist after birth because organs and body systems are structurally or functionally immature at birth, continuing to develop throughout infancy, childhood, and adolescence. Developmental variables may influence the mechanisms or rates of absorption, metabolism, storage, or excretion of toxicants. Any of these factors could alter the concentration of biologically effective toxicant at the target organ(s) or could modulate target organ response to the toxicant. Children's exposures to toxicants may be more extensive than adults' exposures because children consume more food and liquids in proportion to their body weights than adults consume. Infants can ingest toxicants through breast milk, an exposure pathway that often goes unrecognized. Nonetheless, the advantages of breastfeeding outweigh the probability of significant exposure to infants through breast milk and women are encouraged to continue breastfeeding and to limit exposure of their infants by limiting intake of the contaminated foodstuff. Children may experience effects at a lower exposure dose than might adults because children's organs may be more sensitive to the effects of toxicants. Stated differently, children's systems could respond more extensively or with greater severity to a given dose than would an adult organ exposed to an equivalent dose of a toxicant. Children could be more prone to developing certain cancers from chemical exposures than are adults.[36] In any case, if a chemical or a class of chemicals is observed to be, or is thought to be, more toxic to fetuses, infants, or children, the constants (e.g., RfD, MRL, or CPF) are usually modified further to assure the immature systems' potentially greater susceptibilities are not perturbed.[28] Additionally, in accordance with the ATSDR's *Child Health Initiative*[37] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[38] the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults consume. Thus, DSHS recommends that children weighing 35 kg or less and/or who are 11 years of age or younger limit exposure to contaminants in fish or shellfish by eating no more than four ounces per meal of the contaminated species. The DSHS also recommends that consumers spread these meals over time. For instance, if the DSHS issues consumption advice that recommends consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and should not eat such fish or shellfish more than twice per month.

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© files into SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc) and used SPSS® to generate descriptive statistics (mean, standard deviation, median, minimum and maximum concentrations, and range) on measured compounds in each species from each sample site.[39] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values)[c]. PCDFs/PCDDs descriptive statistics are calculated using estimated concentrations (J-values) and assuming zero for PCDFs/PCDDs designated as ND.[d] The change in methodology for computing PCDFs/PCDDS descriptive statistics is due to the proximity of the reporting limits to the HAC value. Assuming ½ the RL for PCDFs/PCDDs designated as ND or J-values would unnecessarily overestimate the concentration of PCDFs/PCDDs in each fish tissue sample. The SALG used the descriptive statistics from the above calculations to generate the present report. The SALG employed Microsoft Excel® spreadsheets to generate figures, to compute HAC_{nonca} and HAC_{ca} values for contaminants, and to calculate HQs, HIs, cancer risk probabilities, and meal consumption limits for fish from Lake Worth.[40] When lead concentrations in fish or shellfish are high, SALG risk assessors may utilize the EPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead-contaminated fish could cause a child's blood lead (PbB) level to exceed the Centers for Disease Control and Prevention's (CDC) lead concentration of concern in children's blood (10 mcg/dL).[41,42]

RESULTS

The GERG laboratory completed analyses and electronically transmitted the results of the Lake Worth samples collected in October 2008 to the SALG on September 11, 2009. The laboratory reported the analytical results for metals, pesticides, PCBs, PCDFs/PCDDs, SVOCs, and VOCs.

For reference, Table 1 summarizes the fish samples collected for this project by site, species, length and weight. Tables 2a through 2c present the results of metals analyses. Tables 3a and 3b contain summary results of pesticides analyses; tables 4a through 4e summarize the PCB analyses, while table 5 presents the analytical results for the PCDFs/PCDDs analyses. This paper does not display SVOC and VOC data because these contaminants were not present at concentrations of interest in fish collected from Lake Worth during the described sampling event. Unless otherwise stated, table summaries present the number of samples containing a specific toxicant/number tested, the mean concentration ± 1 standard deviation (68% of samples should

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[c] *"J-value" is standard laboratory nomenclature for analyte concentrations that are detected and reported below the reporting limit (<RL). The reported concentration is considered an estimate, quantitation of which may be suspect and may not be reproducible. The DSHS treats J-Values as "not detected" in its statistical analyses of a sample set.*

[d] *The SALG risk assessors' rationale for computing PCDFs/PCDDs descriptive statistics using the aforementioned method is based on the proximity of the laboratory reporting limits and the health assessment comparison value for PCDFs/PCDDs. Thus, applying the standard SALG method utilizing ½ the reporting limit for analytes designated as not detected (ND) or estimated (J) will likely overestimate the PCDFs/PCDDs fish tissue concentration.*

fall within one standard deviation of the arithmetic mean in a sample from a normally-distributed population), and, in parentheses under the mean and standard deviation, the minimum and the maximum detected concentrations. Those who prefer to use the range may derive this statistic by subtracting the minimum concentration of a given toxicant from its maximum concentration. In the tables, results may be reported as ND, BDL (below detection limit), or as measured concentrations. According to the laboratory's quality control/quality assurance materials, results reported as "BDL" rely upon the laboratory’s method detection limit (MDL) or its reporting limit (RL). The MDL is the minimum concentration of an analyte that be reported with 99% confidence that the analyte concentration is greater than zero, while the RL is the concentration of an analyte reliably achieved within specified limits of precision and accuracy during routine analyses. Contaminant concentrations reported below the RL are qualified as “J-values” in the data report.[43]

Inorganic Contaminants

Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, and Zinc

A subset of 16 samples was selected from the 80 samples collected from Lake Worth for metals analyses. The 16 samples were comprised of 10 channel catfish and 6 largemouth bass. All 16 fish tissue samples examined from Lake Worth contained concentrations of arsenic, copper, lead, mercury, selenium, and zinc (Tables 2a- 2c).

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All 16 fish tissue samples contained copper (Table 2b). The mean copper concentration in fish sampled from Lake Worth was 0.169±0.038 mg/kg. Channel catfish had the highest average concentration of copper (0.171±0.035 mg/kg). All fish tissue samples assayed contained selenium. The average selenium concentration in fish from Lake Worth was 0.220 mg/kg with a standard deviation of ±0.059 mg/kg (Table 2b). Selenium in fish from Lake Worth ranged from 0.103 to 0.327 mg/kg. All samples examined also contained zinc (Table 2c). The mean zinc concentration in fish tissue samples from Lake Worth was 4.395±0.798 mg/kg.

The SALG evaluated four toxic metalloids having no known human physiological function (arsenic, cadmium, lead, and mercury) in the samples collected from Lake Worth. All 16 fish assayed contained arsenic ranging from 0.050-0.201 mg/kg (Table 2a). Six of 16 fish contained cadmium. One largemouth bass contained lead at a concentration exceeding the laboratory's RL (Table 2b). The two species assayed (channel catfish and largemouth bass) contained lead at low concentrations greater than the RL (Table 2b). The average lead concentration in all fish combined was 0.106±0.136 mg/kg (Table 2b).

All 16 fish samples analyzed contained low mercury concentrations (Table 2b). Channel catfish contained the lowest average mercury concentration (0.095±0.109 mg/kg). The mean mercury concentration in largemouth bass collected from Lake Worth was 0.082±0.045 (Table 2b).

Organic Contaminants

<u>Pesticides</u>

The GERG laboratory analyzed 16 fish comprising two fish species (channel catfish and largemouth bass) for 34 pesticides. All samples examined contained concentrations of aldrin, chlordane, dieldrin, 4,4′-DDD, 4,4′-DDE, 4,4′-DDT, and heptachlor (Tables 3a and 3b). The mean aldrin concentration in channel catfish and largemouth bass collected from Lake Worth was 0.012±0.008 mg/kg (Table 3b). Chlordane concentrations ranged from 0.005-0.105 mg/kg in channel catfish and largemouth bass (Table 3a). Channel catfish contained the highest concentration of dieldrin (0.037 mg/kg; Table 3b). The mean dieldrin concentration in channel catfish and largemouth bass was 0.017±0.014 mg/kg. Channel catfish and largemouth bass contained low concentrations of 4,4′-DDD, 4,4′-DDE, 4,4′-DDT, and heptachlor greater than the RL (Tables 3a and 3b). Endrin was present in one largemouth bass sample at a level well below public health concern (0.012 mg/kg; data not presented).

Trace[e] quantities of 1,2,3,4-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, pentachlorobenzene, hexachlorobenzene, alpha HCH, gamma HCH, delta HCH, pentachloroanisole, mirex, 2,4′-DDD, 2,4′-DDE, and 2,4′-DDT were present in some channel catfish and largemouth bass samples (data not presented).

<u>PCBs</u>

The present study marks the first instance in which the SALG required analysis of fish tissue samples from Lake Worth for PCB congeners rather than Aroclors®. Thus, it is important that readers do not attempt to make direct comparisons between PCB concentrations in this report and Aroclor® concentrations from previous studies of Lake Worth.

All 80 fish tissue samples assayed contained concentrations of one or more PCB congeners (Tables 4a through 4e). No fish sample contained all PCB congeners (data not shown). Across all sites and species, PCB concentrations in fish ranged from 0.009 mg/kg (white crappie) to 0.600 mg/kg (smallmouth buffalo; Table 4e). Two of seven fish species evaluated had mean PCB congener concentrations that exceeded the DSHS HAC_{nonca} for PCBs (0.047 mg/kg; Table 4e). Smallmouth buffalo contained the highest mean concentration of PCBs (0.328±0.150 mg/kg), followed by blue catfish (0.049±0.034 mg/kg), followed by channel catfish (0.037±0.047 mg/kg), followed by common carp (0.031±0.017 mg/kg), followed by largemouth bass (0.020±0.012 mg/kg), and then by freshwater drum (0.018±0.007 mg/kg). White crappie contained the lowest mean concentration of PCBs (0.011 mg/kg; Table 4e). The mean PCB concentration in all 80 fish tissue samples assayed was 0.064±0.116 mg/kg (Table 4e).

The DSHS SALG evaluated the PCB data using univariate analysis of variance (ANOVA) to determine if there were differences in fish tissue PCB concentrations between the 10 Lake Worth

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[e] *Trace: in analytical chemistry, a trace is an extremely small amount of a chemical compound, one present in a sample at a concentration below a standard limit. Trace quantities may be designated with the "less than" (<) sign or may also be represented by the alpha character "J" – called a "J-value" defining the concentration of a substance as near zero or one that is detected at a low level but that is not guaranteed quantitatively replicable.*

sample sites. The ANOVA revealed that there were no differences in fish tissue PCB concentrations between sample sites ($F(9, 70) = 0.371$, $p = 0.944$). Because PCB concentrations did not statistically differ between sample sites, SALG risk assessors used data combined from all sample sites to assess health risks associated with consuming PCB-contaminated fish from Lake Worth.

PCDFs/PCDDs

The GERG laboratory analyzed 16 fish tissue samples for 17 of the 210 possible PCDF/PCDD (135 PCDFs + 75 PCDDs) congeners from Lake Worth. The congeners examined consist of 10 PCDFs and 7 PCDDs that contain chlorine substitutions in, at a minimum, the 2, 3, 7, and 8 positions on the dibenzofuran or dibenzo-*p*-dioxin nucleus and are the only congeners reported to pose dioxin-like adverse human health effects.[44] Although 12 of the 209 PCB congeners – those often referred to as "coplanar PCBs," meaning the molecule can assume a flat configuration with both phenyl rings in the same plane – may also have dioxin-like toxicity, the SALG does not assess PCBs for dioxin-like qualities because the dioxin-like behavior has been less extensively evaluated. Table 5 contains species-specific summary statistics for PCDFs/PCDDs in fish collected from Lake Worth. Before generating summary statistics for PCDFs/PCDDs, the SALG risk assessors converted the reported concentration of each PCDF or PCDD congener reported present in a tissue sample to a concentration equivalent in toxicity to that of 2,3,7,8-TCDD (a TEQ concentration - expressed as pg/g). Twelve of 16 fish tissue samples contained at least one of the 17 congeners assayed (minimum – to – maximum concentration after conversion: ND-0.616 pg/g; Table 5). No samples contained all 17 congeners (data not shown). Channel catfish contained the highest mean TEQ concentration (0.077±0.193 pg/g; Table 5).

SVOCs

A subset of 16 samples was selected from the 80 samples collected from Lake Worth for SVOCs analyses. The laboratory detected no SVOCs in channel catfish and largemouth bass from Lake Worth.

VOCs

The GERG laboratory reported the 16 fish tissue samples selected for analysis from Lake Worth to contain quantifiable concentrations >RL of one or more VOCs: acetone, carbon disulfide, and methylene chloride (data not presented). Trace quantities[f] of most VOCs were also present in one or more fish tissue samples assayed from Lake Worth (data not presented). The *Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual* contains a complete list of the 70 VOCs selected for analysis.[11] **Error! Bookmark not defined.** All VOCs, excluding chloromethane, vinyl chloride, bromomethane, chloroethane, and dichlorodifluoromethane, were also identified in one or more of the procedural blanks, indicating the possibility that these compounds were introduced during sample

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[f] *Trace: in analytical chemistry, a trace is an extremely small amount of a chemical compound, one present in a sample at a concentration below a standard limit. Trace quantities may be designated with the "less than" (<) sign or may also be represented by the alpha character "J" – called a "J-value" defining the concentration of a substance as near zero or one that is detected at a low level but that is not guaranteed quantitatively replicable*

preparation. VOC concentrations <RL are difficult to interpret due to their uncertainty and may represent a false positive. The presence of many VOCs at concentrations <RL may be the result of incomplete removal of the calibration standard from the adsorbent trap, so they are observed in the blank. VOC analytical methodology requires that VOCs are thermally released from the adsorbent trap, transferred to the gas chromatograph (GC), and into the GC/mass spectrometer (MS) for quantification.

DISCUSSION

Risk Characterization

Because variability and uncertainty are inherent to quantitative assessment of risk, the calculated risks of adverse health outcomes from exposure to toxicants can be orders of magnitude above or below actual risks. Variability in calculated and in actual risk may depend upon factors such as the use of animal instead of human studies, use of subchronic rather than chronic studies, interspecies variability, intra-species variability, and database insufficiency. Since most factors used to calculate comparison values result from experimental studies conducted in the laboratory on nonhuman subjects, variability and uncertainty might arise from the study chosen as the "critical" one, the species/strain of animal used in the critical study, the target organ selected as the "critical organ," exposure periods, exposure route, doses, or uncontrolled variations in other conditions.[28] Despite such limitations, risk assessors must calculate parameters to represent potential toxicity to humans who consume contaminants in fish and other environmental media. The DSHS calculated risk parameters for systemic and cancerous endpoints in those who would consume fish from Lake Worth. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of findings to risk. Meal consumption calculations are integral to the SALG's risk characterizations and are used by DSHS risk managers to determine whether consumption advice or regulatory actions might be necessary to protect human health from adverse effects of consuming toxicants in fish from Texas waters.

Characterization of Systemic (Noncancerous) Health Effects from Consumption of Fish from Lake Worth

PCBs were observed in fish from Lake Worth that equaled or exceeded their respective HAC_{nonca}(Tables 4a through 4e). No species of fish collected from Lake Worth contained any other inorganic or organic contaminants at concentrations that equaled or exceeded the DSHS guidelines for protection of human health or would likely cause systemic risk to human health from consumption of fish from Lake Worth. Potential systemic health risks related to the consumption of fish from Lake Worth containing inorganic and organic contaminants (other than PCBs) are not of public health concern. Consequently, this risk characterization concentrates on assessing the likelihood of systemic adverse health outcomes that could occur from consumption of Lake Worth PCB-contaminated fish. Tables 6 through 7 provide hazard quotients for mercury, PCBs, and PCDFs/PCDDs in each species of fish collected from Lake Worth and the recommended weekly consumption rate for each species.

PCBs

All fish collected from Lake Worth in 2008 contained PCBs (Tables 4a through 4e). Mean PCB concentrations for two (blue catfish and smallmouth buffalo) of seven fish species assayed exceeded the HAC_{nonca} for PCBs or an HQ of 1.0 (Tables 4e and 7). The *All Species* mean PCB concentration (0.064 mg/kg) also exceeded the HAC_{nonca} for PCBs or an HQ of 1.0 (Tables 4e and 7) representing a potential systemic health risk related to the consumption of fish from Lake Worth. However, it is important to note that the *All Species* mean PCB concentration is inflated due to the high PCB concentrations observed in smallmouth buffalo. By removing the smallmouth buffalo samples from the sample set, the *All Species* mean PCB concentration (N = 70; 0.026±0.028 mg/kg) does not exceed the HAC_{nonca} for PCBs or an HQ of 1.0.

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of 8-ounce meals of fish from Lake Worth that healthy adults could consume by species without significant risk of adverse systemic effects (Table 7). The SALG estimated this group could consume 0.9 (8-ounce) meals per week of blue catfish or 0.1 (8-ounce) meals per week of smallmouth buffalo (Table 7). The meal consumption calculations suggest that blue catfish and smallmouth buffalo from Lake Worth contain PCBs at concentrations that could result in adverse systemic effects on human health and that adults should limit their consumption of blue catfish and should not consume any smallmouth buffalo. The developing nervous system of the human fetus may be especially susceptible to these effects.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from Lake Worth

The USEPA classifies arsenic, most chlorinated pesticides, PCBs, and PCDFs/PCDDs as carcinogens. Although arsenic, PCDFs/PCDDs, and many chlorinated pesticides were present in samples from Lake Worth, none of these contaminants evaluated singly were observed at concentrations that would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Table 8). PCB concentrations observed in smallmouth buffalo would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Table 8). PCBs concentrations observed in all other fish species collected from Lake Worth would not be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Table 8).

The SALG risk assessors calculated the number of 8-ounce meals of fish from Lake Worth that healthy adults could consume by species without significant risk of adverse carcinogenic effects (Table 8). The SALG estimated this group could consume 0.8 (8-ounce) meals per week of smallmouth buffalo (Table 8). The meal consumption calculations suggest that smallmouth buffalo from Lake Worth contain multiple contaminants at concentrations that that would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals and adults should limit their consumption of smallmouth buffalo. Based on the meal calculations for adverse systemic effects on human health, DSHS risk assessors recommend no consumption of smallmouth buffalo from Lake Worth. The developing nervous system of the human fetus may be especially susceptible to these effects.

Characterization of Calculated Cumulative Systemic Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from Lake Worth

Cumulative systemic effects of toxicants may occur if more than one contaminant acts upon the same target organ or acts by the same mode or mechanism of action. PCBs and PCDFs/PCDDs in Lake Worth fish could have these properties, especially with respect to effects on the immune system. Aldrin and dieldrin also act by a similar mechanism of action exhibiting effects on the liver. Multiple inorganic or organic contaminants in the Lake Worth samples did not increase the likelihood of systemic adverse health outcomes from consuming any species of fish from Lake Worth above that of the DSHS' guidelines for protection of human health (HI $\geq$ 1.0; Table 7).

The SALG also queried the probability of increasing lifetime excess cancer risk from consuming fish containing multiple inorganic and organic contaminants. Consumption of multiple contaminants (aldrin, dieldrin, PCBs, and PCDFs/PCDDs) in channel catfish from Lake Worth did increase the calculated lifetime excess cancer risk to a risk level that exceeds the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Table 8). Because channel catfish and largemouth bass were the only two fish species examined for chlorinated pesticides, DSHS risk assessors were unable to evaluate cumulative excess lifetime cancer risks completely for other fish species. It is important to be aware that these cumulative carcinogenic effects may also be apparent in other fish species.

The SALG risk assessors calculated the number of 8-ounce meals of fish from Lake Worth that healthy adults could consume by species without significant risk of adverse carcinogenic effects (Table 8). The SALG estimated this group could consume 0.6 (8-ounce) meals per week of channel catfish or 3.6 (8-ounce) meals per week of largemouth bass (Table 8). The meal consumption calculations suggest that channel catfish from Lake Worth contain multiple contaminants at concentrations that would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals, thus, adults should limit their consumption of channel catfish. The developing nervous system of the human fetus may be especially susceptible to these effects.

CONCLUSIONS

SALG risk assessors prepare risk characterizations to determine public health hazards from consumption of fish and shellfish harvested from Texas water bodies by recreational or subsistence fishers. If necessary, SALG may suggest strategies for reducing risk to the health of those who may eat contaminated fish or seafood to risk managers at DSHS, including the Texas Commissioner of Health.

This study addressed the public health implications of consuming fish from Lake Worth, located in Tarrant County, Texas. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming fish from Lake Worth that:

1. Common carp, freshwater drum, largemouth bass, and white crappie do not contain any inorganic or organic contaminant concentrations, either singly or cumulatively, that exceed DSHS guidelines for protection of human health. Therefore, consumption of these fish species **poses no apparent risk to human health**.

2. Blue catfish and smallmouth buffalo from Lake Worth contain PCBs at concentrations exceeding DSHS guidelines for protection of human health. Regular or long-term consumption of blue catfish and smallmouth buffalo from Lake Worth may result in adverse systemic health effects. Therefore, consumption of blue catfish and smallmouth buffalo from Lake Worth **poses an apparent risk to human health**.

3. Smallmouth buffalo contain PCBs at concentrations exceeding DSHS guidelines for protection of human health of one excess cancer in 10,000 equally exposed individuals. Regular or long-term consumption of smallmouth buffalo from Lake Worth may significantly increase the likelihood of carcinogenic health risks. Therefore, consumption of smallmouth buffalo **poses an apparent risk to human health**.

4. Consumption of multiple organic contaminants (aldrin, dieldrin, PCBs, and PCDFS/PCDDs) in channel catfish from Lake Worth may significantly increase the likelihood of carcinogenic health risks. Therefore, consumption of channel catfish **poses an apparent risk to human health**.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the USEPA.[12, 14, 45] Risk managers at the DSHS may decide to take some action to protect public health if a risk characterization confirms that people can eat four, or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) of fish or shellfish from a water body under investigation. Risk management recommendations may be in the form of consumption advice or a ban on possession of fish from the affected water body. Fish or shellfish possession bans are enforceable under subchapter D of the Texas Health and Safety Code, part 436.061(a).[46] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[46] DSHS consumption advice carries no penalty for noncompliance. Consumption advisories, instead, inform the public of potential health hazards associated with consuming contaminated fish or shellfish from Texas waters. With this information, members of the public can make informed decisions about whether and/or how much – contaminated fish or shellfish they wish to consume. The SALG concludes from this risk characterization that consuming blue catfish, channel catfish, and smallmouth buffalo from Lake Worth **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:

1. Pregnant women, women who may become pregnant, women who are nursing, infants, and children less than 12 years of age or who weigh less than 75 pounds should not consume blue catfish, channel catfish, and smallmouth buffalo from Lake Worth.

2. Adult men and women past childbearing age should not consume blue catfish, channel catfish, and smallmouth buffalo from Lake Worth.

3. As resources become available, the DSHS should continue to monitor fish from Lake Worth for changes or trends in contaminants or contaminant concentrations that would necessitate a change in consumption advice.

PUBLIC HEALTH ACTION PLAN

Communication to the public of new and continuing possession bans or consumption advisories, or the removal of either, is essential to effective management of risk from consuming contaminated fish. In fulfillment of the responsibility for communication, the Texas Department of State Health Services (DSHS) takes several steps. The agency publishes fish consumption advisories and bans in a booklet available to the public through the Seafood and Aquatic Life Group (SALG). To receive the booklet and/or the data, please contact the SALG at 512-834-6757.[47] The SALG also posts the most current information about advisories, bans, and the removal of either on the internet at http://www.dshs.state.tx.us/seafood. The SALG regularly updates this Web site. The DSHS also provides USEPA (http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the Texas Parks and Wildlife Department (TPWD) (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans on it's Web site and in an official hunting and fishing regulations booklet available at many state parks and at all establishments selling Texas fishing licenses.[48] Readers may direct questions about the scientific information or recommendations in this risk characterization to the SALG at 512-834-6757 or may find the information at the SALG's Web site (http://www.dshs.state.tx.us/seafood). Secondarily, one may address inquiries to the Environmental and Injury Epidemiology and Toxicology Unit of the Department of State Health Services (512-458-7269). The USEPA's IRIS Web site (http://www.epa.gov/iris/) contains information on environmental contaminants found in food and environmental media. The Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology (888-42-ATSDR or 888-422-8737) or the ATSDR's Web site (http://www.atsdr.cdc.gov) supplies brief information via ToxFAQs.™ ToxFAQs™ are available on the ATSDR Web site in either English (http://www.atsdr.cdc.gov/toxfaq.html) or Spanish (http://www.atsdr.cdc.gov/es/toxfaqs/es_toxfaqs.html). The ATSDR also publishes more in-depth reviews of many toxic substances in its *Toxicological Profiles* (ToxProfiles™). To request a copy of the ToxProfiles™ CD-ROM, PHS, or ToxFAQs™ call 1-800-CDC-INFO (800-232-4636) or email a request to cdcinfo@cdc.gov.

Figure 1. Lake Worth Sample Sites

TABLES

Table 1. Fish samples collected from Lake Worth on October 13, 2008 through October 16, 2008. Sample number, species, length, and weight were recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Lake Worth at the Dam			
LWO104	Channel catfish	547	1801
LWO101	Channel catfish	505	1129
LWO98	Common carp	540	2147
LWO100	Freshwater drum	487	1418
LWO97	Largemouth bass	584	3925
LWO95	Largemouth bass	483	1737
LWO93	Largemouth bass	474	1828
LWO30	Smallmouth buffalo	675	6315
LWO29	White crappie	310	395
Site 2 Lake Worth near the Naval Air Station			
LWO23	Channel catfish	571	1707
LWO24	Channel catfish	480	942
LWO74	Common carp	544	2243
LWO25	Smallmouth buffalo	695	7059
Site 3 Lake Worth near Carswell Field Runway			
LWO124	Channel catfish	575	1615
LWO14	Channel catfish	532	1241
LWO15	Channel catfish	512	1026
LWO13	Channel catfish	479	805
LWO120	Common carp	600	3010
LWO122	Freshwater drum	563	1778
LWO22	Freshwater drum	557	2429
LWO121	Freshwater drum	518	2154
LWO113	Largemouth bass	507	1832
LWO115	Largemouth bass	377	669
LWO21	Smallmouth buffalo	605	4942
LWO18	White crappie	338	536
LWO17	White crappie	321	548
LWO19	White crappie	277	301

Table 1 Continued. Fish samples collected from Lake Worth on October 13, 2008 through October 16, 2008. Sample number, species, length, and weight were recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 4 Lake Worth near Meandering Creek Road			
LWO41	Channel catfish	564	1374
LWO42	Common carp	566	2324
LWO43	Freshwater drum	543	1890
LWO32	Largemouth bass	464	1295
LWO34	Largemouth bass	455	1433
LWO26	Smallmouth buffalo	745	9257
LWO39	White crappie	365	751
Site 5 Lake Worth at Woods Inlet			
LWO10	Channel catfish	529	1345
LWO112	Channel catfish	505	1083
LWO105	Common carp	646	3884
LWO109	Freshwater drum	360	487
LWO31	Largemouth bass	449	1119
LWO107	Largemouth bass	416	893
LWO108	Largemouth bass	415	1113
LWO12	Smallmouth buffalo	657	6907
LWO11	White crappie	395	427
LWO110	White crappie	305	332
Site 6 Lake Worth at Live Oak Creek Mouth			
LWO8	Blue catfish	580	1812
LWO45	Channel catfish	439	621
LWO48	Common carp	530	1960
LWO47	Freshwater drum	445	1130
LWO44	Largemouth bass	381	741
LWO9	Smallmouth buffalo	620	6146
LWO50	White crappie	303	419
Site 7 Lake Worth near Woods Island			
LWO4	Blue catfish	730	4377
LWO2	Channel catfish	619	2423
LWO55	Channel catfish	594	1844
LWO3	Channel catfish	547	1347
LWO53	Largemouth bass	426	1048
LWO52	Largemouth bass	368	593
LWO5	Smallmouth buffalo	665	6804

Table 1 Continued. Fish samples collected from Lake Worth on October 13, 2008 through October 16, 2008. Sample number, species, length, and weight were recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 8 Lake Worth near Mosque Point			
LWO64	Channel catfish	430	581
LWO63	Common carp	606	2957
LWO62	Freshwater drum	418	975
LWO57	Largemouth bass	485	1775
LWO58	Largemouth bass	444	1216
LWO6	Smallmouth buffalo	680	6364
Site 9 Lake Worth at SH 199 Bridge			
LWO73	Channel catfish	505	1070
LWO72	Common carp	599	2920
LWO70	Freshwater drum	560	2630
LWO67	Largemouth bass	385	732
LWO7	Smallmouth buffalo	730	7918
LWO68	White crappie	297	369
Site 10 Lake Worth at West Fork Trinity River			
LWO88	Blue catfish	704	3812
LWO89	Blue catfish	676	3642
LWO90	Channel catfish	475	736
LWO86	Common carp	559	2059
LWO76	Freshwater drum	479	1816
LWO78	Largemouth bass	466	1523
LWO80	Largemouth bass	400	909
LWO79	Largemouth bass	367	665
LWO87	Smallmouth buffalo	751	7488
LWO82	White crappie	318	454

Table 2a. Arsenic (mg/kg) in fish collected from Lake Worth, 2008.					
Species	**# Detected/ # Sampled**	**Total Arsenic Mean Concentration ± S.D. (Min-Max)**	**Inorganic Arsenic Mean Concentration[g]**	**Health Assessment Comparison Value (mg/kg)[h]**	**Basis for Comparison Value**
Channel catfish	10/10	0.125±0.049 (0.050-0.190)	0.013	0.7 0.362	EPA chronic oral RfD for Inorganic arsenic: 0.0003 mg/kg–day EPA oral slope factor for inorganic arsenic: 1.5 per mg/kg–day
Largemouth bass	6/6	0.134±0.062 (0.062-0.201)	0.013		
All fish combined	16/16	0.128±0.053 (0.050-0.201)	0.013		

[g] *Most arsenic in fish and shellfish occurs as organic arsenic, considered virtually nontoxic. For risk assessment calculations, DSHS assumes that total arsenic is composed of 10% inorganic arsenic in fish and shellfish tissues.*
[h] *Derived from the MRL or RfD for noncarcinogens or the USEPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of 1x10^{-4}.*

Table 2b. Inorganic contaminants (mg/kg) in fish collected from Lake Worth, 2008.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Cadmium				
Channel catfish	4/10	BDL[i]	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Largemouth bass	2/6	0.009±0.002 (BDL-0.010)		
All fish combined	6/16	0.011±0.005 (ND[j]-0.027)		
Copper				
Channel catfish	10/10	0.171±0.035 (0.128-0.215)	333	National Academy of Science Upper Limit: 0.143 mg/kg–day
Largemouth bass	6/6	0.166±0.047 (0.108-0.240)		
All fish combined	16/16	0.169±0.038 (0.108-0.240)		
Lead				
Channel catfish	10/10	0.112±0.166 (BDL-0.573)	NA	Lead Model Version 1.1 Build 9
Largemouth bass	6/6	0.097±0.077 (BDL-0.219)		
All fish combined	16/16	0.106±0.136 (BDL-0.573)		
Mercury				
Channel catfish	10/10	0.095±0.109 (BDL-0.316	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Largemouth bass	6/6	0.082±0.045 (0.032-0.129)		
All fish combined	16/16	0.090±0.089 (BDL-0.316)		
Selenium				
Channel catfish	10/10	0.225±0.040 (0.178-0.279)	6	EPA chronic oral RfD: 0 .005 mg/kg–day ATSDR chronic oral MRL: 0.005 mg/kg–day NAS UL: 0.400 mg/day (0.005 mg/kg–day) RfD or MRL/2: (0.005 mg/kg –day/2= 0.0025 mg/kg–day) to account for other sources of selenium in the diet
Largemouth bass	6/6	0.212±0.087 (0.103-0.327)		
All fish combined	16/16	0.220±0.059 (0.103-0.327)		

[i] *BDL: "Below Detection Limit" – Concentrations were reported as less than the laboratory's reporting limit ("J" values). In some instances, a "J" value was used to denote the discernable presence in a sample of a contaminant at concentrations estimated as different from the sample blank.*

[j] *ND: "Not Detected" was used to indicate that a compound was not present in a sample at a level greater than the reporting limit.*

Table 2c. Inorganic contaminants (mg/kg) in fish collected from Lake Worth, 2008.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Zinc				
Channel catfish	10/10	4.389±0.555 (3.726-5.476)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Largemouth bass	6/6	4.405±1.164 (3.002-5.759)		
All fish combined	16/16	4.395±0.798 (3.002-5.759)		

Table 3a. Pesticides (mg/kg) in fish collected from Lake Worth, 2008				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
β-hexachlorocyclohexane				
Channel catfish	6/10	0.0008±0.0008 (ND-0.002)	0.3	EPA slope factor 1.8 mg/kg-day
Largemouth bass	4/6	0.0006±0.0007 (ND-0.002)		
All fish combined	10/16	0.0007±0.0007 (ND-0.002)		
Heptachlor				
Channel catfish	10/10	0.010±0.005 (0.003-0.018)	1.167 0.121	EPA chronic oral RfD: 0.0005 mg/kg–day EPA slope factor 4.5 per mg/kg-day
Largemouth bass	6/6	0.003±0.0006 (0.002-0.004)		
All fish combined	16/16	0.007±0.005 (0.002-0.018)		
Chlordane				
Channel catfish	10/10	0.023±0.029 (0.007-0.105)	1.167 1.553	EPA chronic oral RfD: 0.0005 mg/kg–day EPA slope factor 0.35 per mg/kg-day
Largemouth bass	6/6	0.005±0.0005 (0.048-0.006)		
All fish combined	16/16	0.016±0.024 (0.005-0.105)		

Table 3b. Pesticides (mg/kg) in fish collected from Lake Worth, 2008				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Aldrin				
Channel catfish	10/10	0.017±0.005 (0.010-0.024)	0.07	EPA chronic oral RFD: 0.00003 mg/kg–day
Largemouth bass	6/6	0.004±0.001 (0.002-0.005)	0.032	EPA slope factor 17 mg/kg-day
All fish combined	16/16	0.012±0.008 (0.002-0.024)		
Dieldrin				
Channel catfish	10/10	0.026±0.010 (0.009-**0.037**[k])	0.117	EPA chronic oral RfD: 0.00005 mg/kg–day
Largemouth bass	6/6	0.002±0.0005 (0.001-0.003)	0.034	EPA slope factor 16 per mg/kg-day
All fish combined	16/16	0.017±0.014 (0.001-**0.037**)		
4,4′-DDE				
Channel catfish	10/10	0.009±0.012 (0.002-0.041)	1.167	EPA chronic oral RfD: 0.0005 mg/kg–day
Largemouth bass	6/6	0.003±0.001 (0.002-0.005)	1.599	EPA slope factor 0.35 per mg/kg-day
All fish combined	16/16	0.006±0.010 (0.002-0.041)		
4,4′-DDD				
Channel catfish	10/10	0.001±0.001 (BDL-0.003)	1.167	EPA chronic oral RfD: 0.0005 mg/kg–day
Largemouth bass	6/6	BDL	2.27	EPA slope factor 0.24 per mg/kg-day
All fish combined	16/16	0.0007±0.0008 (BDL-0.003)		
4,4′-DDT				
Channel catfish	10/10	0.002±0.0007 (0.0006-0.002)	1.167	EPA chronic oral RfD: 0.0005 mg/kg–day
Largemouth bass	6/6	0.0006±0.0004 (BDL-0.001)	1.599	EPA slope factor 0.34 per mg/kg-day
All fish combined	16/16	0.001±0.0009 (BDL-0.003)		

[k] ***Emboldened numbers*** *indicate the concentration of a contaminant exceeded a DSHS HAC Value.*

Table 4a. PCBs (mg/kg) in fish collected from Lake Worth, 2008.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 1 at the Dam				
Channel catfish	2/2	0.021±0.003 (0.018-0.023)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	0.019		
Freshwater drum	1/1	0.012		
Largemouth bass	3/3	0.027±0.013 (0.014-0.039)		
Smallmouth buffalo	1/1	**0.399**[1]		
White crappie	1/1	0.010		
All fish combined	9/9	**0.062**±0.127 (0.010-**0.399**)		
Site 2 near the Naval Air Station				
Channel catfish	2/2	0.016±0.00004 (0.0161-0.0162)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	0.019		
Smallmouth buffalo	1/1	**0.341**		
All fish combined	4/4	**0.098**±0.162 (0.016-**0.341**)		
Site 3 near Carswell Field Runway				
Channel catfish	4/4	0.027±0.010 (0.018-0.040)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	0.044		
Freshwater drum	3/3	0.020±0.009 (0.010-0.029)		
Largemouth bass	2/2	0.038±0.027 (0.019-**0.057**)		
Smallmouth buffalo	1/1	**0.207**		
White crappie	3/3	0.010±0.0002 (0.0100-0.0101)		
All fish combined	14/14	0.037±0.051 (0.010-**0.207**)		

[1] ***Emboldened numbers*** *indicate the concentration of a contaminant exceeded a DSHS HAC Value.*

Table 4b. PCBs (mg/kg) in fish collected from Lake Worth, 2008.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 4 near Meandering Creek Road				
Channel catfish	1/1	**0.078**[m]	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	**0.056**		
Freshwater drum	1/1	0.025		
Largemouth bass	2/2	0.024±0.018 (0.012-0.037)		
Smallmouth buffalo	1/1	**0.600**		
White crappie	1/1	0.011		
All fish combined	7/7	**0.117**±0.214 (0.011-**0.600**)		
Site 5 at Woods Inlet				
Channel catfish	2/2	0.027±0.023 (0.011-0.043)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	**0.056**		
Freshwater drum	1/1	0.011		
Largemouth bass	3/3	0.018±0.004 (0.014-0.022)		
Smallmouth buffalo	1/1	**0.527**		
White crappie	2/2	0.012±0.003 (0.010-0.014)		
All fish combined	10/10	**0.073**±0.160 (0.010-**0.527**)		

[m] ***Emboldened numbers*** *indicate the concentration of a contaminant exceeded a DSHS HAC Value.*

Table 4c. PCBs (mg/kg) in fish collected from Lake Worth, 2008.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 6 at Live Oak Creek Mouth				
Blue catfish	1/1	0.018	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Channel catfish	1/1	0.016		
Common carp	1/1	0.016		
Freshwater drum	1/1	0.020		
Largemouth bass	1/1	0.011		
Smallmouth buffalo	1/1	**0.300**[n]		
White crappie	1/1	0.009		
All fish combined	7/7	**0.056**±0.108 (0.009-**0.300**)		
Site 7 near Woods Island				
Blue catfish	1/1	0.022	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Channel catfish	3/3	0.020±0.007 (0.016-0.028)		
Largemouth bass	2/2	0.011±0.001 (0.010-0.011)		
Smallmouth buffalo	1/1	**0.190**		
All fish combined	7/7	0.042±0.065 (0.010-**0.190**)		
Site 8 near Mosque Point				
Channel catfish	1/1	**0.213**	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	0.038		
Freshwater drum	1/1	0.010		
Largemouth bass	2/2	0.019±0.007 (0.014-0.024)		
Smallmouth buffalo	1/1	**0.221**		
All fish combined	6/6	0.087±0.101 (0.010-0.221)		

[n] ***Emboldened numbers*** *indicate the concentration of a contaminant exceeded a DSHS HAC Value.*

Table 4d. PCBs (mg/kg) in fish collected from Lake Worth, 2008.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 9 at SH 199 Bridge				
Channel catfish	1/1	0.045	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	0.014		
Freshwater drum	1/1	0.018		
Largemouth bass	1/1	0.011		
Smallmouth buffalo	1/1	**0.357**[o]		
White crappie	1/1	0.010		
All fish combined	6/6	**0.076**±0.138 (0.010-**0.357**)		
Site 10 at West Fork Trinity River				
Blue catfish	2/2	**0.079**±0.006 (**0.075-0.083**)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Channel catfish	1/1	0.025		
Common carp	1/1	0.021		
Freshwater drum	1/1	0.024		
Largemouth bass	3/3	0.012±0.001 (0.011-0.013)		
Smallmouth buffalo	1/1	**0.134**		
White crappie	1/1	0.014		
All fish combined	10/10	0.041±0.042 (0.011-**0.134**)		

[o] ***Emboldened numbers*** *indicate the concentration of a contaminant exceeded a DSHS HAC Value.*

Table 4e. PCBs (mg/kg) in fish collected from Lake Worth, 2008.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
All Sampling Sites				
Blue catfish	4/4	**0.049**[p]±0.034 (0.018-**0.083**)		
Channel catfish	18/18	0.037±0.047 (0.011-**0.213**)		
Common carp	9/9	0.031±0.017 (0.014-**0.056**)		
Freshwater drum	10/10	0.018±0.007 (0.010-0.029)	0.047	EPA chronic oral RfD: 0.00002 mg/kg–day
Largemouth bass	19/19	0.020±0.012 (0.010-**0.057**)	0.272	EPA slope factor: 2.0 per mg/kg–day
Smallmouth buffalo	10/10	**0.328**±0.150 (**0.134**-**0.600**)		
White crappie	10/10	0.011±0.002 (0.009-0.014)		
All fish combined	80/80	**0.064**±0.116 (0.009-**0.600**)		

[p] ***Emboldened numbers*** *indicate the concentration of a contaminant exceeded a DSHS HAC Value.*

Table 5. PCDFs/PCDDs toxicity equivalent concentrations (TEQ; pg/g) in fish collected from the Lake Worth, 2008.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
PCDFs/PCDDs				
Channel catfish	8/10	0.077±0.193 (ND-0.616)	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
Largemouth bass	4/6	BDL	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
All fish combined	12/16	0.048±0.154 (BDL-0.616)		

Table 6. Hazard quotients (HQs) for mercury in fish collected from Lake Worth in 2008. Table 6 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[q]		
Species	**Hazard Quotient**	**Meals per Week**
Channel catfish	0.1	6.8
Largemouth bass	0.1	7.9
All fish combined	0.1	7.2

[q] *DSHS assumes that children under the age of 12 years and/or those who weigh less than 35 kg eat 4-ounce meals*

Table 7. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and PCDFs/PCDDs in fish species collected in 2008 from Lake Worth. Table 7 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[r]			
Species/Contaminant	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Blue Catfish			
PCBs	4	**1.1**[s]	**0.9**[t]
Channel catfish			
PCBs	18	0.8	1.2
PCDFs/PCDDs	10	<0.1	*Unrestricted*
Hazard Index (meals per week)		0.8 (1.1)	
Common carp			
PCBs	9	0.7	1.4
Freshwater drum			
PCBs	7	0.4	2.4
Largemouth bass			
PCBs	19	0.4	2.2
PCDFs/PCDDs	6	<0.1	*Unrestricted*
Hazard Index (meals per week)		0.1 (7.9)	
Smallmouth buffalo			
PCBs	10	**7.0**	**0.1**
White crappie			
PCBs	10	0.2	4.0
All fish combined			
PCBs	80	**1.4**	**0.7**
PCDFs/PCDDs	16	<0.1	*Unrestricted*
Hazard Index (meals per week)		**1.4 (0.7)**	

[r] *DSHS assumes that children under the age of 12 years and/or those who weigh less than 35 kg eat 4-ounce meals.*
[s] **Emboldened numbers** denote the HQ for PCBs exceeds 1.0
[t] **Emboldened numbers** denote the calculated allowable meal consumption rate for an adult is less than one/week

Table 8a. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing PCBs and PCDFs/PCDDs collected in 2008 from Lake Worth and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Lake Worth over a 30-year period.[r]				
Species/Contaminant	**Number (N)**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**1 excess cancer per number of people exposed**	
Blue catfish				
PCBs	4	1.8E-05	55,097	5.1
Channel catfish				
PCBs	18	1.4E-05	72,933	6.7
Aldrin	10	5.2E-05	19,189	1.8
Dieldrin	10	7.6E-05	13,113	1.2
PCDFs/PCDDs	10	2.2E-06	451,083	*Unrestricted*
Cumulative Cancer Risk		**1.4E-04**[u]	**6,930**	**0.6**[v]
Common carp				
PCBs	9	1.2E-05	86,438	8.0
Freshwater drum				
PCBs	7	6.6E-06	152,642	14.1
Largemouth bass				
PCBs	19	7.2E-06	138,143	12.8
Aldrin	6	1.2E-05	85,069	7.9
Dieldrin	6	6.2E-06	160,131	14.8
PCDFs/PCDDs	6	6.3E-09	158,637,659	*Unrestricted*
Cumulative Cancer Risk		2.5E-05	39,443	3.2
Smallmouth buffalo				
PCBs	10	**1.2E-04**	**8,310**	**0.8**
White crappie				
PCBs	10	4.0E-06	251,755	*Unrestricted*

[u] ***Emboldened numbers*** *denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1 X 10^{-4}*
[v] ***Emboldened numbers*** *denote the calculated meal consumption rate for adults is less than one per week*

Table 8b. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing PCBs and PCDFs/PCDDs collected in 2008 from Lake Worth and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Lake Worth over a 30-year period.[r]

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
All fish combined				
PCBs	80	2.3E-05	42,789	4.0
PCDDs/PCDFs	16	1.4E-06	720,485	*Unrestricted*
Cumulative Cancer Risk		2.5E-05	40,390	3.7

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